Ideal Point Method Applied in Forest Harvest Regulation

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Abstract   Ideal point method is one of the methods to solve multi-objective problem. It is applied to forest harvest regulation, and showed very good results by analyzing changes of quantitative indexes of forest resource structure before and after the regulation. This method can be applied as one of the mathematical tools in forest harvest regulation.

Key words: Ideal point method, Forest harvest regulation, Forest structure, Quantitative index, Ohm's distance, Equilibrium ratio

Introduction[1][2]

Supposing there are m objective $f_1(x)$, $f_2(x)$, ... $f_m(x)$, each objective has its optimal solution or optimal value:

$$f_i^o = MAXf_i(X^{(i)})$$

$$x \in R \qquad i=1, 2, ..., m$$

If $i=1, 2, ...$, m, one of any values is taken in m series, $x^{(i)}$ will be same, it is x^0, then $x=x^0$, every objective may reach its optimal point. In fact, it is very difficult to realize this situation because of complexity among objective. Therefore, in the following vector function:

$$F(x) = (f_1(x), f_2(x), ... f_m(x))^T$$

vector $F^0 = (f_1^0, f_2^0, ... f_m^0)^T$ is only an ideal point.

Ideal point method was raised by Салуквализе. The kernel of this method is to find a point which mostly approaches the ideal point with the help of a defined model, That is

$$\|F(X-)F^o\| \rightarrow \min\|F(X) - F^o\|$$

In general, the following defined model P is used as evaluating function.

$$\left\|F(X) - F^o\right\| = \left[\sum_{i=1}^{m}(f_i^o - f_i(X))^p\right]^{1/P}$$

Where:$1 \leqslant p \leqslant \infty$ $L_p(x)$ is named as model P of $(F(x)-$

$F^0)$ whose implication is distance.

When $p=1$, $L_1(X) = \sum_{i=1}^{m}\left[f_1^0 - f_1(X)\right]$

So as to find min. $L_1(x)$, that is actually to find x_0, to find the minimum sum of absolute values from each fraction difference. That is to find the minimum deviation.

When $p=2$, $L_2(x)$ is the distance between vector $F(x)$ and vector F^0 in a common Ohm's space, where geometric implication is a straight line, that is the shortest distance between two points.

When $p=\infty$, $L_\infty(X) = \max\left|f_i^o - f_i(X)\right|$
$$1 \leq i \leq m$$

When p > 2, the distance is shorter than straight line distance between the two points, and the greater the p is, the more the value of distance approaches a bigger component (attribute, objective). Therefore, different p values might be taken to reflect different favorite extents towards bigger components. The ideal point method were used to forest harvest regulation for larch forest type in Qianqiugou Firest Farm, Shanxi Province.

Building up a Model of Multi-objective Policy

Constitution of the constraint conditions

Supposing the cutting area of management period i and age class j was x_{ij}. The constraint conditions were constituted according to forest site properties conditions for permanent utilization and requirements by policymaker in Qianqiugou, Shanxi Province. Through repeated cal-

culations, comparison and analysis with many schemes, the larch forest type harvest chart was drawn (It was left out in the paper) and constraints conditions were determined as follows:

Objective age class restraint　　Through 8 management regulation periods, areas of 6 age classes (The rotation is age of 60) were relatively well distributed, while variation was within ± 10% of the mean area of each age class.

Cutting area restraint for each age class　　Stands of age class VIII must be cut completely within the management regulation period; stands of age classes I - III should not be cut. Sites that had been cut should be regenerated within one regulation period.

The maximum cutting volume restraint　　Cutting volume was smaller than growth volume. The minimum cutting volume restraint: cutting volume should be greater than annual cutting volume required by balance point between gain and loss[3][4].

Non-negative Restraint According to requirement, other constrains may be added.

Objectives of forest harvest regulation　　The objectives of forest harvest regulation indicated that certain consequences would follow under specific restraint conditions set by forest management workers. Choosing goal is very important. Different goal will lead different result. According to the principles of "Sustaining Development and Everlasting Utilization", avoiding resource crisis and economic dilemma, the maximum pure timber selling profit, the minimum management cost and the maximum amount of timber yielding during the regulation period were chosen as the objectives in the paper.

The maximum pure timber selling profit might be reached by:

$$MAX\ NPV=\sum_{i=1}^{q}\left[\sum_{j=m}^{r}f_{ij}V_{ij}X_{ij}\ /(1+p)\right]^{t}$$

Where i was management stage; j was felling age; V_{ij} was timber output per unit area during stage i and age class j; f_{ij} was net income per unit area; x_{ij} was felling area in stage i and age class j; t was discount time; p was discount rate.

The minimum management cost might be realized by:

$$MIN\ NC=\sum_{i=1}^{q}\left[\sum_{j=m}^{r}c_{ij}X_{ij}\ /(1+p)^{t}\right]$$

Where c_{ij} was management cost in stage i and age class j; others were the same as in above formula.

The maximum amount of timber yielding might be reached by:

$$MAX\ V=\sum_{i=1}^{q}\sum_{j=m}^{r}a_{j}X_{ij}$$

Where a_j was standing volume per unit area during stage i and for age class j. To improve accuracy of parameters in the model, and to avoid random fluctuation of stock volume caused by stochastic error in investigation along with age variation, so as to find rational solutions by the model, the following regression formula was drawn up in accordance with the relationship between stocks per unit area and ages:

$$a_j=223,0406(1-e^{(-0.1000j)})^{16.8246}$$
$$r=0.9498\quad s_{xy}=0.0916$$

Where a_j was stock volume per unit area for age class j. Stock volume per unit area a_j was calculated by above formula. Solutions from every single objective value of Harvest Regulations was got by the linear programming according to the same constraints. When $p=1$, solutions found by above formula[5] were listed in Table 1:

Table 1.　　Situation from harvest regulation　　(unit: ha)

Age class	Management Stage							
	I	II	III	IV	V	VI	VII	VIII
IV	0.0	0.0	0.0	0.0	273.4	0.0	0.0	
V	0.0	0.0	0.0	30.5	0.0	258.6	334.2	217.3
VI	0.0	0.0	0.0	163.8	0.0	0.0	0.0	116.9
VII	480.2	58.9	28.8	44.1	0.0	0.0	0.0	0.0
VIII	51.8	467.4	461.9	35.0	0.0	0.0	0.0	0.0

Values of objective functions were as follows: the maximum pure profit of timber selling was 1297105.60 yuan; the minimum management cost was 314642.70 yuan; the maximum value timber yielding was 629411.60 m³.

Evaluation for Result of Forest Regulation

Ideal point method presents some goals, then sets some objective functions and examines the objective functions how to reach these goals. It has been proved that the solutions found in this way will definitely be noninferior ones, which are naturally effective points in the objective value space [1].

The main purpose of forest harvest regulation is to adjust forest structure. Therefore indexes that are applied to evaluate forest structure can be taken as the quantitative indexes to evaluate the effects of forest har-

vest regulation. The Ohm's distance and equilibrium ratio were selected to be the indexes to evaluate the change of forest structure on Qianqiugou Forest Farm before and after the forest harvest regulation [6][7][8]. The smaller Ohms distance is, the better forest structure is .The value of equilibrium is between 0 and 1. The bigger equilibrium is, the better forest structure is . The Ohm's distance before the forest harvest regulation was 1122.3; while it changed to be 74.3 after the regulation. Equilibrium ratios before and after the regulation are 0.24 and 0.94 respectively. By comparing the variation of quantitative indexes of forest structure of forest farm before and after forest yielding regulation. It can be concluded that the forest yielding regulation would reach obvious and expected effect.

Conclusions

Ideal point method was applied to solve forest harvest regulation problem for Larch forest type in Qianqiugou Forest Farm, Shanxi Province, in the paper. Effects of the regulation were significant. Expected aims were reached, which were demonstrated by analyzing the forest structure changes before and after the forest regu-

lation. It is recommended that ideal point method is a mathematical tool for undertaking forest harvest regulation.

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